Bean Tunnel

Technical Note on Ground Settlement Adjacent to Proposed Cofferdam Excavation – Bluewater Parkway

Balfour Beatty Temporary Works Department

CRXC0062-BBMP-00-XX-TN-W-0001 P01

12/01/22

Produced By:

Jack Ellis

Reviewed By:

Blendi Feruku

Revision Schedule				
Rev	**Reason**	**Author**	**Reviewer**	**Issue Date**
P01	First Issue	JE	BF	12/01/22

Technical Note on Ground Settlement Adjacent to Proposed Cofferdam Excavation – Bluewater Parkway

Introduction

This technical note covers how the settlement contours around the proposed new reed bed and gabion wall excavation cofferdam have been determined, as per reference drawing CRXC0062-BBMP-00-XX-DR-W-0002 P02 (Appendix 1).

Input Information

The Thames Water Main affected (reference technical note BRT-TG-XX-ZZ-TN-UT-0001 for more details on the water main) is approximately 5.2m from the cofferdam at it nearest point and at a depth of 1.3m below pavement as per figure 1.

Also adjacent to the excavation is an existing substation. The surcharge of this has been calculated as 50kPa, consisting of approximated dead load, live load, and additional factor of safety.

Figure 1: Cofferdam and adjacent Thames Water main location

A general surcharge of 10kPa has been considered.

The ground properties have been determined from borehole BHRH1 which consists of made ground and sands and gravels above a chalk layer. SPT values in the made ground vary from N=2 to N=32, corresponding to an angle of internal friction (phi) of 27° to 37°. Ground water has been considered at -2.20mAOD. Borehole provided in Appendix 3.

Cofferdam details are as per Groundforce design 82962 P03 (Appendix 2).

Idealisations and Assumptions

The settlement analysis has been carried out in accordance with CIRIA C760 (Guidance on embedded retaining wall design) [1]. Which is followed by GEO5 Sheeting Check software used in this analysis.

As stated in the CIRIA guidance, ground movements cannot be predicted exactly, but can be estimated based on previous field measurements in comparable conditions, the empirical relationship between lateral deflections and settlement and from previous experience.

The analysis undertaken here considered the empirical relationship between wall deflection and settlement, similar to figure 2 taken from CIRIA C760.

Figure 2: Relationship between analysed lateral (propped) wall deflections and predicted ground surface settlements in stiff ground (CIRIA C760 p170)

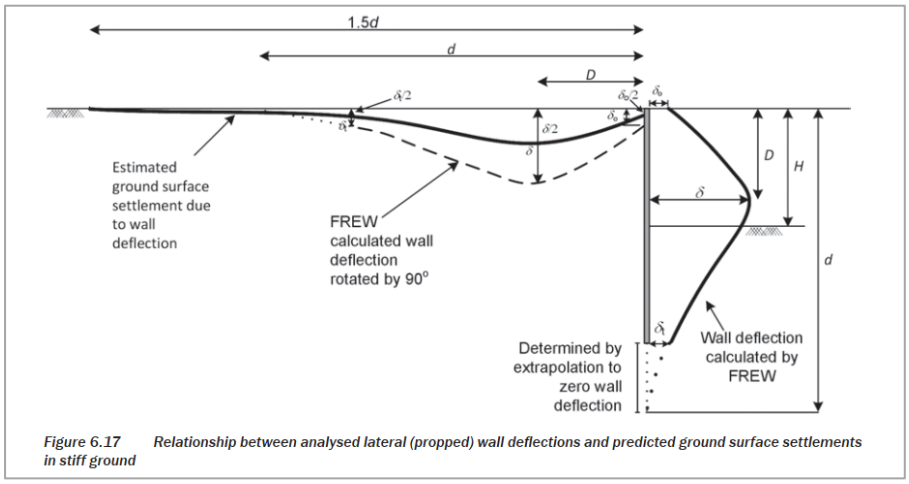


Figure 6.17 Relationship between analysed lateral (propped) wall deflections and predicted ground surface settlements in stiff ground

No additional stiffness at the corners of the excavation has been considered.

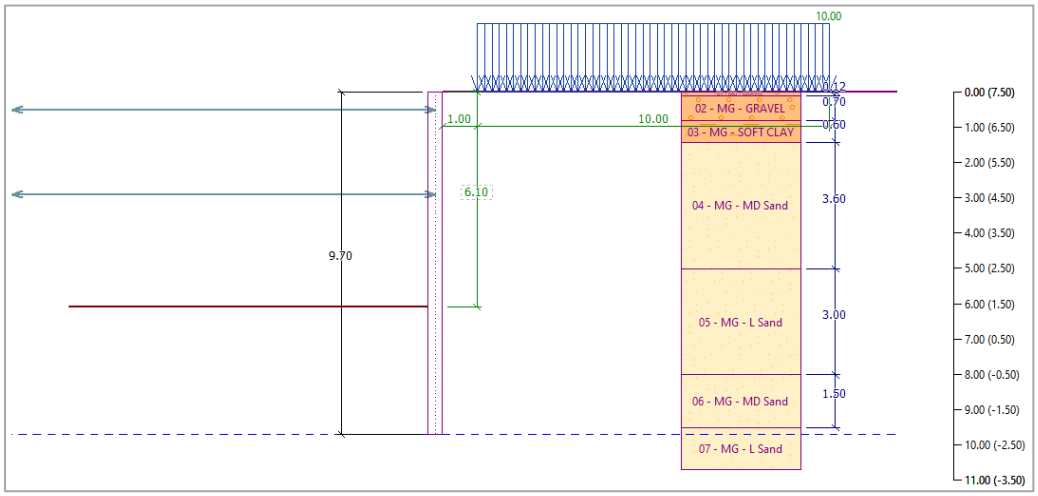
Assessment methodology

The settlement analysis has been carried out using GEO5 Sheeting Check software, as this provides a direct output for settlement. The output forces and displacements have been compared with Geosolve WALLAP as a comparison with industry standard software to confirm their accuracy.

Analysis was carried out to Eurocode 7, under SLS conditions. The software carries out the assessment based on a subgrade reaction model.

The analysis model was carried out for all stages of construction to progressively install the cofferdam and props. The settlement analysis was carried out for two sections, one at the substation and one with a general surcharge of 10kPa. The input model at the final stage is shown in figure 3.

Figure 3: GEO5 final stage input model

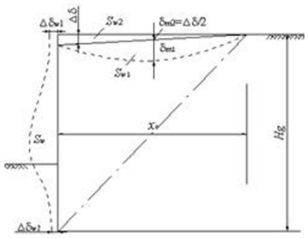


Bean Tunnel: Technical Note on Ground Settlement Adjacent to Proposed Cofferdam Excavation – Bluewater Parkway

The GEO5 'parabolic method' for settlement has been used as per the details below in figure 4 taken from the software help guidance[2]. This follows the CIRIA C760 assumptions and calculated settlement based on lateral deflections and the total deformed area, based on Peck theory.

Figure 4: GEO5 Settlement calculation

$$\delta(x) = 4 \cdot \delta_{max} \cdot \frac{x \cdot (x_0 - x)}{x_0^2} + \Delta\delta \cdot \frac{x_0 - x}{x_0}$$



$$\Delta\delta = \frac{1}{2} \cdot (\delta_{w1} + \delta_{w2})$$

$$\delta_{max} = \frac{1.6 \cdot s_w}{x_0} - 0.3 \cdot \Delta\delta$$

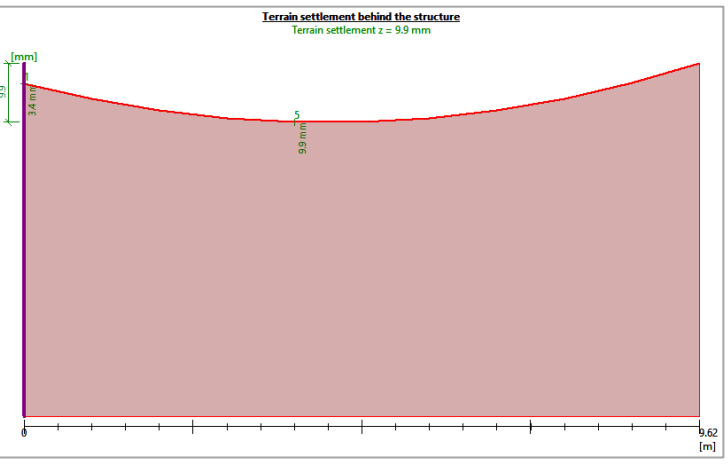
where:

δ_{max}	-	maximum settlement
s_w	-	area formed by deformed structure and un-deformed structure
x_0	-	range of settlement
$\delta(x)$	-	settlement at each point within the range of settlement x_0 in distance x
x	-	distance between the calculation point and the edge of the foundation pit
δ_{w1}	-	horizontal displacement at the top of the structure
δ_{w2}	-	horizontal displacement at the bottom of the structure

Output

The direct output results taken from GEO5 software are shown in figure 5 below.

Figure 5: GEO5 Settlement model results



Terrain settlement behind the structure
Terrain settlement δ_{max} = 8.2 mm

	Coordinates x [m]	Settlement z [mm]
1	0.00	3.4
2	0.96	6.0
3	1.92	8.0
4	2.88	9.3
5	3.85	9.9
6	4.81	9.9
7	5.77	9.2
8	6.73	7.9
9	7.69	5.9
10	8.65	3.3
11	9.62	0.0

Conclusion

These results have been plotted as contours on drawing CRXC0062-BBMP-00-XX-DR-W-0002 P02 and used by Tony Gee to assess the pipe strains in the Thames Water main as per BRT-TG-XX-ZZ-TN-UT-0001.

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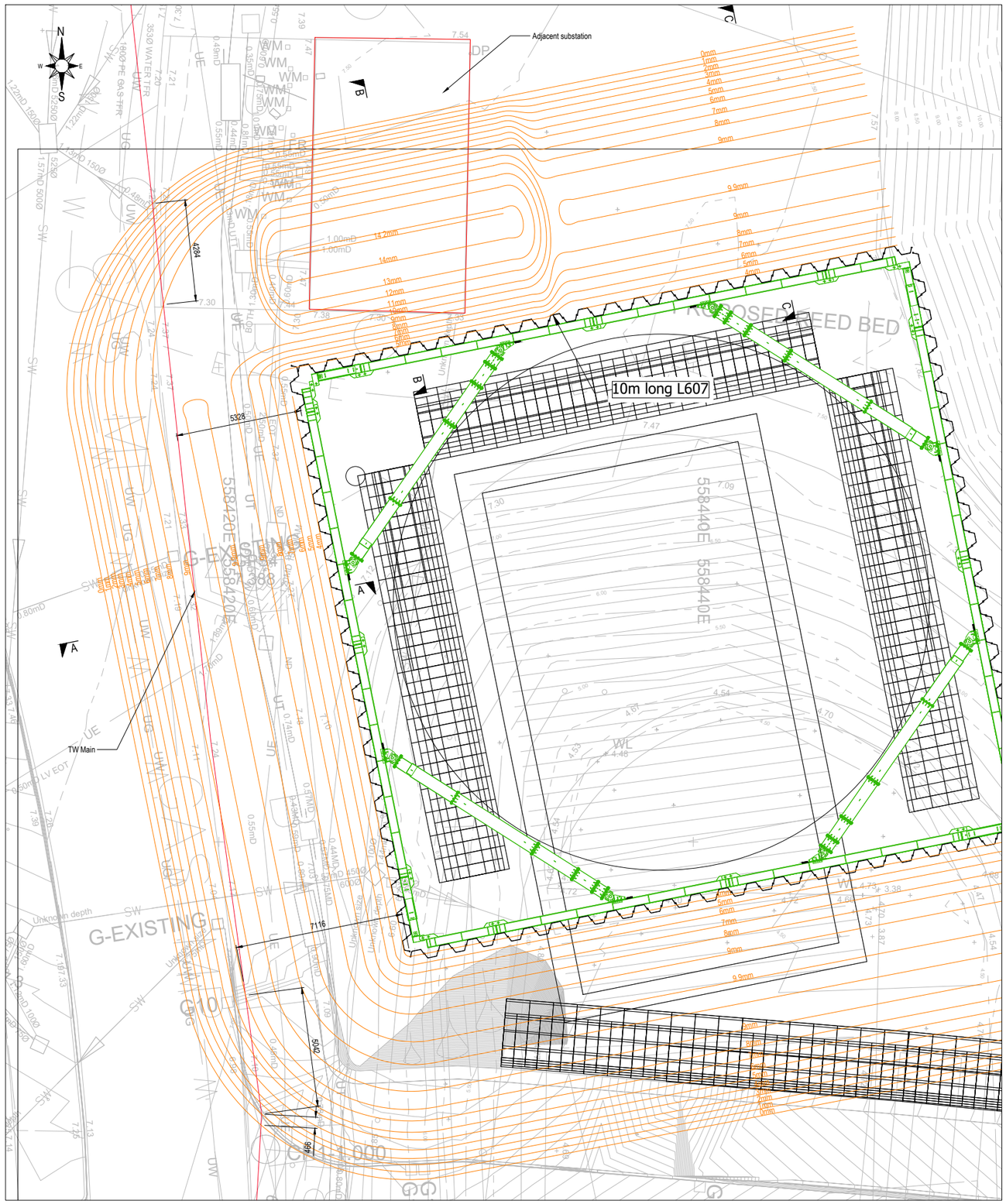
[1] CIRIA C760 - Guidance on embedded retaining wall design
[2] https://www.finesoftware.eu/help/geo5/en/parabolic-method-01/

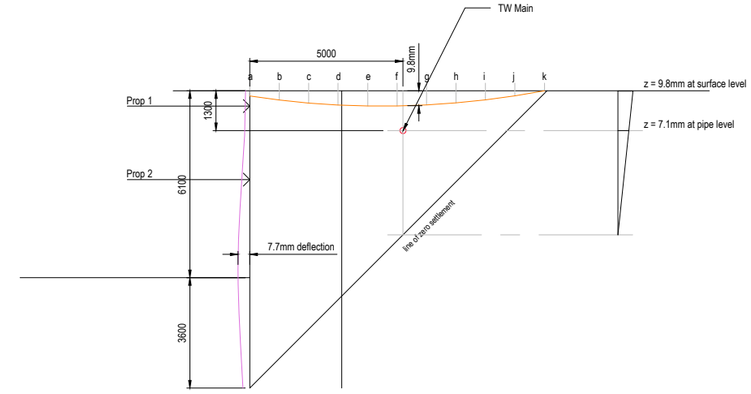
Appendix 1

Drawing CRXC0062-BBMP-00-XX-DR-W-0002 P02

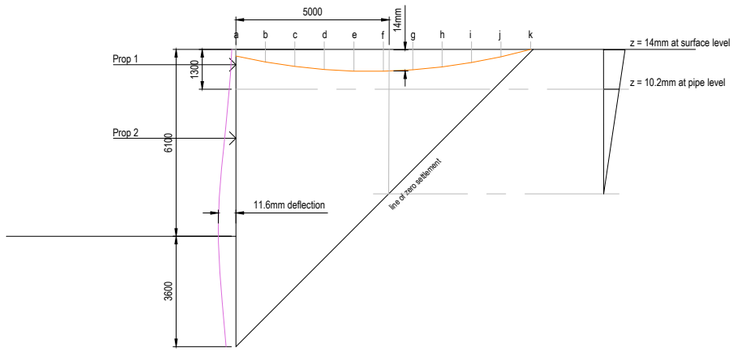
Hazard Triangles indicate residual risks from the Design Risk Assessment
Details can be found in the Health, Safety and Environmental Risk box



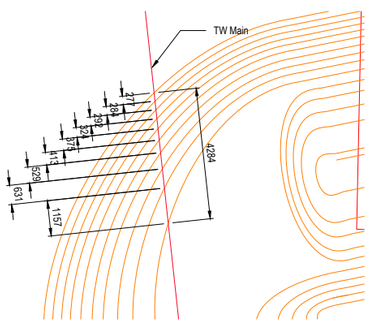
Settlement Contours
Scale 1:100



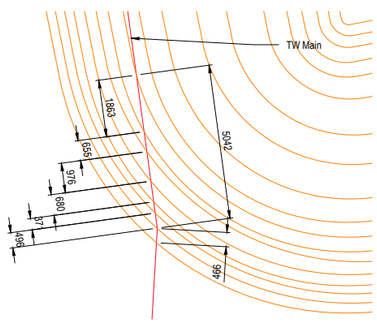
Section A-A (and C-C)
Scale 1:100



Section B-B
Scale 1:100



NW Corner Detail
Scale 1:100



SW Corner Detail
Scale 1:100

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Location Plan

Health, Safety and Environmental Risks

Risk Assessment Number	N/A
Risk No	Risk
N/A	N/A
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ZERO HARM MAKE SAFETY PERSONAL | SUSTAINABILITY a collective responsibility

Notes

1. If anything on this drawing changes, contact TWC or TWD.
2. Groundforce cofferdam design obtained from 82962/AN/101 P03
3. Settlements/deflections scaled by 50x on sections
4. Section A-A Settlements - ref. report dated 14/12/21 - Cofferdam (Surcharge)
   - 4.1. a (0mm offset) - 3.4mm settlement
   - 4.2. b (960 offset) - 6.0 settlement
   - 4.3. c (1920 offset) - 8.0 settlement
   - 4.4. d (2880 offset) - 9.3 settlement
   - 4.5. e (3850 offset) - 9.9 settlement
   - 4.6. f (4810 offset) - 9.9 settlement
   - 4.7. g (5770 offset) - 9.2 settlement
   - 4.8. h (6730 offset) - 7.9 settlement
   - 4.9. i (7690 offset) - 5.9 settlement
   - 4.10. j (8650 offset) - 3.3 settlement
   - 4.11. k (9620 offset) - 0 settlement
5. Section B-B Settlements ref. report dated 14/12/21 - Cofferdam (Substation)
   - 5.1. a (0mm offset) - 4.3mm settlement
   - 5.2. b (960 offset) - 8.2 settlement
   - 5.3. c (1920 offset) - 11.1 settlement
   - 5.4. d (2880 offset) - 13.1 settlement
   - 5.5. e (3850 offset) - 14.1 settlement
   - 5.6. f (4810 offset) - 14.2 settlement
   - 5.7. g (5770 offset) - 13.3 settlement
   - 5.8. h (6730 offset) - 11.4 settlement
   - 5.9. i (7690 offset) - 8.6 settlement
   - 5.10. j (8650 offset) - 4.8 settlement
   - 5.11. k (9620 offset) - 0 settlement
6. Background graphics obtained from BRT-TG-XX-ZZ-DR-UT-0151 P03 and BRT-TG-XX-ZZ-DR-HI-0501 P03
7. Dimensions in mm UNO.

Document History

Revision	Description	Date	Des	Chck
P01	For Discussion	14/12/21	JE	N/A
P02	For Discussion	15/12/21	JE	N/A
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Designer

Balfour Beatty

"Driving Innovative Temporary Works Design and Engineering Excellence"

Client

Paper Size	Scale	Designer	Checker
A1	As Shown	JE	N/A

Project

Bean Tunnel

Drawing Title

Excavation and removal of existing reed bed
Settlement contours

Status

Preliminary

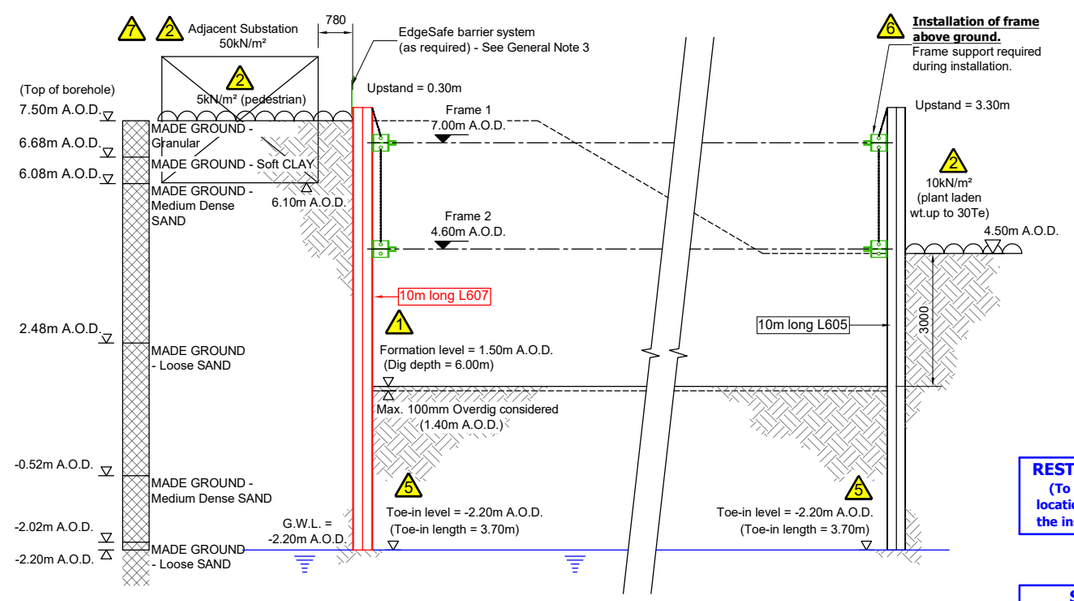
Client Drawing Number	Revision
N/A	N/A

Drawing Number	Revision
CRXC0062-BBMP-00-XX-DR-W-0002	P02

Appendix 2

Drawing 82962 P03

File Location: \\VPFP06\Home\GF_Technical_South\Designs\Shoring Schemes\Technical South\Arpad Nagy\82962 - Balfour Beatty Utilities - Bean (GME)\3. Drawing\82962.dwg



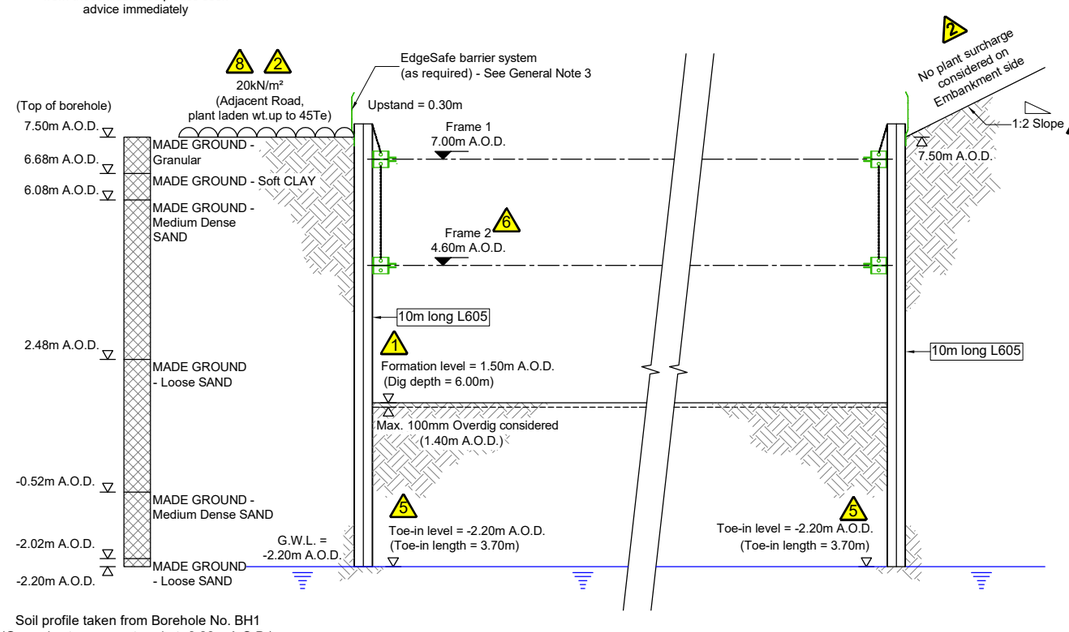
Soil profile taken from Borehole No. BHRH1
(Groundwater encountered at -2.22m A.O.D.)

⚠ Note: If soil properties and water level (if applicable) varies significantly from those illustrated please seek advice immediately

Cross Section A - A

RESTRAINING CHAINS
(To be attached at these locations in accordance with the installation instructions)

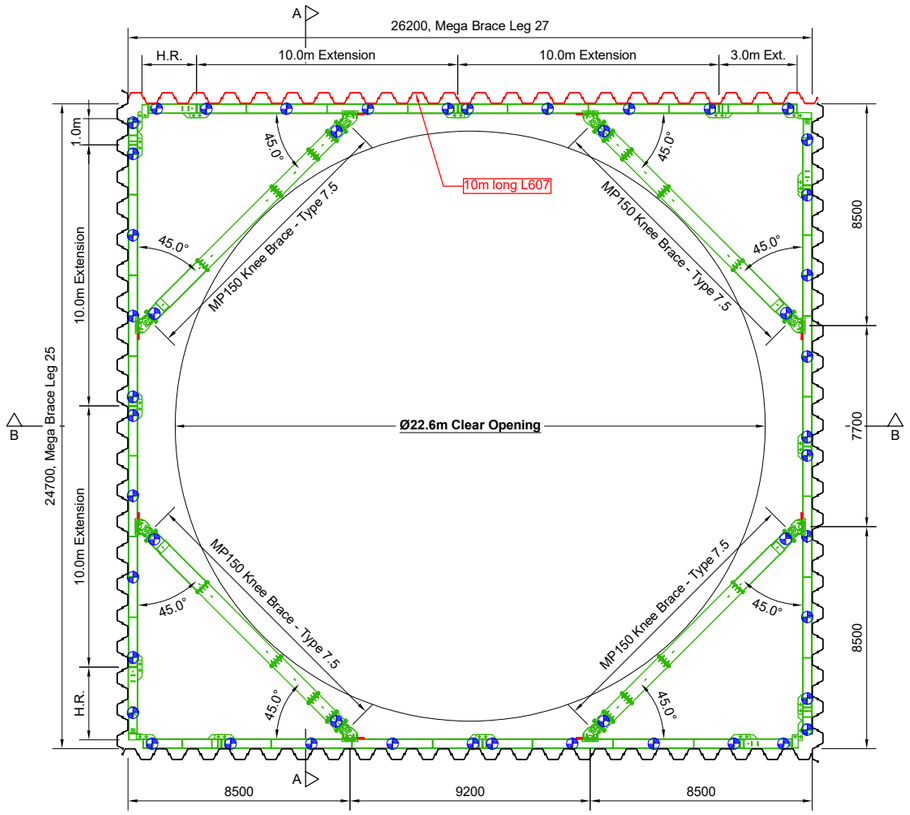
SHEAR STOPS
(To be attached at these locations in accordance with the installation instructions)


7 2 No plant surcharge considered on Embankment side
8 2 20kN/m² (Adjacent Road, plant laden wt.up to 45Te)
EdgeSafe barrier system (as required) - See General Note 3
1:2 Slope 9
(Top of borehole)
7.50m A.O.D.
Upstand = 0.30m
Frame 1
7.00m A.O.D.
7.50m A.O.D.
6.68m A.O.D.
MADE GROUND - Granular
6.08m A.O.D.
MADE GROUND - Soft CLAY
MADE GROUND - Medium Dense SAND
Frame 2
4.60m A.O.D.
6
10m long L605
10m long L605
2.48m A.O.D.
1 Formation level = 1.50m A.O.D.
(Dig depth = 6.00m)
MADE GROUND - Loose SAND
Max. 100mm Overdig considered (1.40m A.O.D.)
-0.52m A.O.D.
MADE GROUND - Medium Dense SAND
5 Toe-in level = -2.20m A.O.D.
(Toe-in length = 3.70m)
5 Toe-in level = -2.20m A.O.D.
(Toe-in length = 3.70m)
-2.02m A.O.D.
G.W.L. = -2.20m A.O.D.
-2.20m A.O.D.
MADE GROUND - Loose SAND

Soil profile taken from Borehole No. BH1
(Groundwater encountered at -2.22m A.O.D.)

⚠ Note: If soil properties and water level (if applicable) varies significantly from those illustrated please seek advice immediately

Cross Section B - B



Plan View of Frames 1 & 2

Stage 1
- Pre-Drive the sheets to a depth of -2.20m AOD.
- Excavate to 6.70m AOD.
- Install Frame 1 at 7.00m AOD.

Stage 2
- After installing Frame 1, excavate to 4.30m AOD.
- Install Frame 2 at 4.60m AOD.

Stage 3
After installing Frame 2, excavate to formation level at 1.50m AOD.

Installation Sequence (Pre-Driven)

⚠ Please note: A 100mm allowance for over dig has been considered within this design. If overdig occurs, contractor to backfill to formation level.

⚠ If the specified toe-in cannot be achieved, an additional temporary frame will be required until a suitable blinding/base slab has been cast.

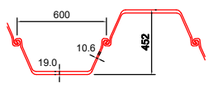
FRAME LOADS

Level	Frame type	Calculated frame load (kN/m)	Allowable frame load (kN/m)	Deflection (mm)
Frame 1 7.00m AOD	Mega c/w MP150 Knee Brace	54.0	107.6	<30
Frame 2 4.60m AOD	Mega c/w MP150 Knee Brace	89.9	107.6	<30

SHEETS BENDING MOMENT

Larssen L607
(Clutched Sheet Pile)

Weight per sheet = 114.0 kg/m
Weight per m of wall = 190.0 kg/m²

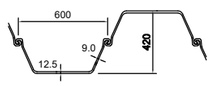


Cross Section Area (cm²)	Section Modulus (cm³/m)	Moment of Inertia (cm⁴/m)	Maximum B. Moment (kNm/m)	Calculated B. Moment (kNm/m)	Maximum Deflection (mm)	Sheet Length (m)
145.9	3200.1	69599.8	640.0	175.1	<15	10.0

SHEETS BENDING MOMENT

Larssen L605
(Clutched Sheet Pile)

Weight per sheet = 83.5 kg/m
Weight per m of wall = 139.2 kg/m²



Cross Section Area (cm²)	Section Modulus (cm³/m)	Moment of Inertia (cm⁴/m)	Maximum B. Moment (kNm/m)	Calculated B. Moment (kNm/m)	Maximum Deflection (mm)	Sheet Length (m)
107.0	2019.9	42370.3	404	224.8	<30	10.0

PRELIMINARY ISSUE ONLY
(FOR DISCUSSION & REVIEW ONLY - NOT FOR CHECKING OR CONSTRUCTION)

SCHEDULE OF WEIGHT

No.	DESCRIPTION:	WEIGHT PER ITEM (kg)
MEGA BRACE		
8	Hydraulic Ram	1120
4	1.0m Mega Extension	410
4	3.0m Mega Extension	760
16	10.0m Mega Extension	2075
MP150 STRUTS		
8	MP150 - Type 7.5 Hyd' Strut	3608
SHEETS		
128	10.0m Long Larssen L605	835
44	10.0m Long Larssen L607	1140
ANCILLARIES		
96	Restraining Chains	7
16	Welded Shear Stop 1500kN	19

DO NOT SCALE FROM DRAWING. IF IN DOUBT, ASK

Notes:

1. Two frames are installed in the excavation at 7.00m and 4.60m A.O.D. respectively.

2. Two types of sheet are required:
   a. On the Substation side, the sheets are Larssen L607 (10.0m long)
   b. On all other sides, the sheets are Larssen L605 (10.0m long)
   All the sheets are to be pre-driven to a depth of -2.20m A.O.D. prior to excavating (to include a toe of 3.70m at final stage).

3. The proposed scheme has been designed as a "propped cantilever" that is with a twinned frame in the upper half of excavation. The scheme therefore relies totally on the specified toe-in of the sheets for stability. If this toe-in cannot be achieved, a temporary lower frame will be required until a suitable blinding/base slab has been cast.

4. Knee braces require welded shear stops, all welds to be completed at the Groundforce depot prior to delivery.

5. The maximum design dig depth is 6.00m (Formation Level at 1.50m A.O.D.). Additionally, the design allows for a 100mm overdig. The contractor must ensure that the excavation is controlled and no further over-dig occurs.

General Notes.

1. Attention is drawn to current safety legislation particularly CDM 2015 regulations & BS 5975:2019. Appropriate site specific risk assessments must be performed by the contractor. In addition the excavation must be inspected by a competent person in accordance with statutory requirements. Any defects or signs of deterioration to the support system must be notified to Groundforce immediately and work stopped within the excavation.

2. Your attention is drawn to the size and weight of the equipment to be supplied as specified. It is the hirer's responsibility to ensure that this information is taken into account during the planning of any work to be carried out, including the provision of adequate lifting facilities to ensure the safe loading, installation and removal of the equipment.

3. In accordance with current Working at Height legislation, it is strongly recommended that the contractor provides suitable edge protection and appropriate means of access and egress to and around the excavation. Groundforce's integrated EdgeSafe and LadderSafe products are recommended.

4. The installation of the equipment is the responsibility of the hirer. It is essential that appropriately trained personnel are employed to install this equipment in accordance with this drawing and specific Groundforce installation user guides. Groundforce can provide an installation supervision service if required or alternatively provide 'toolbox training' for the site operatives.

5. The contractor must provide suitable means to control the inflow of any water into the excavation.

6. Unless specified, the excavation support design does NOT allow for standard BS8002 overdig. The contractor MUST ensure the excavation process is controlled and monitored at all stages to avoid overdigging.

SIGNIFICANT / RESIDUAL RISKS
These must be assessed by the contractor prior to commencing the works

1. Overdig - refer to *General Note No.6*
2. Surcharge - should not exceed design values
3. Unable to fully pre-drive sheets - if refusal is met on significant amount of sheets, design needs to be reassessed
4. Vibration settlement - potential damage to adjacent structures to be assessed and monitored by the contractor
5. **Lack of toe-in - if not achievable, seek advice from Groundforce**
6. **Frame above ground - frame support to be assessed during installation**
7. Integrity of adjacent structure - contractor to assess and monitor integrity of adjacent structure
8. Integrity of adjacent road - contractor to assess and monitor integrity of adjacent road
9. Global failure - potential for global rotational failure of the slope due to the removal of spoil

Rev	Date	Comments	Des	Drw	Chk
-	-	-	-	-	-
P03	08/07/21	Reduced Depth / Two Level of Frame	RAH	SDC	DRP
P02	22/04/21	Revised Depth / Plan Dims. / Surcharges	GME	SDC	DRP
P01	01/04/21	Preliminary Issue	GME	SDC	DRP

Groundforce Shorco
Excavation Support

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The Pinnacles, Rear of Shield House, Elizabeth Way
Harlow, CM19 5AR

Tel: +44 (0)1279 456 060
www.vpgroundforce.com/gb/
technical@vpplc.com

Title:	Reed Bed Construction - Phase 1	Designed by:	RAH	Date:	08/07/21
		Drawn by:	SDC	Date:	08/07/21
Project:	Bluewater, Bean	Checked by:	DRP	Date:	08/07/21
Client:	Balfour Beatty Utilities	Drawing Ref:	82962/AN/101	Rev:	P03
				Drawing Status:	P Prelim
				Paper Size:	A2

Appendix 3

Borehole BHRH1

Rotary Core Log

Project Name: BEAN UNDERPASS	Client: BALFOUR BEATTY	Date: 16/11/2020
Location: DARTFORD	Contractor:	Co-ords: E558435.57 N173541.56
Project No. : GRO-20331	Crew Name:	Drilling Equipment:

Borehole Number	Hole Type	Level	Logged By	Scale	Page Number
BHRH1	CP+RC	7.48m AoD	CW	1:50	Sheet 1 of 2

Well	Water	Depth (m)	Type /FI	Coring TCR	Coring SCR	Coring RQD	Diameter Recovery (SPT)	Depth (m)	Level (m)	Legend	Stratum Description
		0.20	ES					0.10	7.38		MADE GROUND Brown slightly clayey sandy gravelly topsoil. Gravel is angular to subangular fine to coarse brick, chert and concrete. Contains rootlets.
		0.50	B								
		0.50	D								
		0.50 - 1.00	ES					0.80	6.68		MADE GROUND: Brown sandy angular to subangular fine to coarse gravel of mixed lithologies including chert and rare brick.
		1.00	D								
		1.00	ES				(32)				
		1.20 - 1.65	B					1.40	6.08		MADE GROUND: Soft brown slightly gravelly clay. Gravel is angular to subangular medium of mixed lithologis including chalk and chert.
		1.20 - 1.70	D								
		1.80	D								
		2.00	B				(15)				MADE GROUND: Loose to medium dense brown slightly silty fine to medium sand. (Reworked).
		2.00 - 2.45	D								
		2.00 - 2.50	ES								
		2.50	D								
		3.00	B				(15)				
		3.00 - 3.45	D								
		3.00 - 3.50	ES								
		3.50	D								
		4.00	B				(19)				
		4.00 - 4.45	D								
		4.00 - 4.50	ES								
		4.50	D								
		5.00	B				(2)				
		5.00 - 5.45	D								
		5.00 - 5.50	ES								
		6.00	B								
		6.00 - 6.50	D								
		6.50 - 6.95	D				(6)				
		7.00 - 7.50	B								
		7.50	D								*Occasional subangular cobbles of chert recovered at 7.5m bgl.*
		8.00 - 8.45	B				(23)				
		8.00 - 8.50	D								
		9.00	D								
		9.50 - 10.00	B				(11)				
	▼	9.50 - 9.95	D								
		10.00	ES								

Hole Diameter		Casing Diameter		Chiselling				Inclination and Orientation				Drilling Flush					
Depth Base	Diameter	Depth Base	Diameter	Depth Top	Depth Base	Duration	Tool	Depth Top	Depth Base	Inclination	Orientation	Depth Top	Depth Base	Type	Colour	Min (%)	Max (%)

Remarks

1. Location cleared by specialist utility surveyor. 2. Inspection pit dug to 1.2m bgl. 3. Groundwater encountered at 12.5m bgl rising to 9.7m bgl after 20 minutes. 4. Installation to 14.0m bgl- 13.0m plain pipe and 1.0m slotted pipe.

Rotary Core Log

Project Name: BEAN UNDERPASS	Client: BALFOUR BEATTY	Date: 16/11/2020
Location: DARTFORD	Contractor:	Co-ords: E558435.57 N173541.56
Project No. : GRO-20331	Crew Name:	Drilling Equipment:

Borehole Number	Hole Type	Level	Logged By	Scale	Page Number
BHRH1	CP+RC	7.48m AoD	CW	1:50	Sheet 2 of 2

Well	Water	Depth (m)	Type /Fl	Coring TCR	Coring SCR	Coring RQD	Diameter Recovery (SPT)	Depth (m)	Level (m)	Legend	Stratum Description
		10.50	D								MADE GROUND: Loose to medium dense brown slightly silty fine to medium sand. (Reworked).
		11.00 - 11.45 11.00 - 11.50	B D				(2)				
		12.00	D								
		12.50 - 12.95 12.50 - 13.00	B D				(50)	12.50	-5.02		Structureless CHALK composed of slightly sandy silty subangular to subrounded GRAVEL and COBBLES. Clasts are very weak and weak, low and medium density, white with occasional chert . Matrix is white, occasionally light brown. (Grade Dc).
		13.50	D								
		14.50 - 14.87 14.50 - 15.00	B D				(46)	15.00	-7.52		End of Borehole at 15.000m

Hole Diameter		Casing Diameter		Chiselling				Inclination and Orientation				Drilling Flush					
Depth Base	Diameter	Depth Base	Diameter	Depth Top	Depth Base	Duration	Tool	Depth Top	Depth Base	Inclination	Orientation	Depth Top	Depth Base	Type	Colour	Min (%)	Max (%)

Remarks

1. Location cleared by specialist utility surveyor. 2. Inspection pit dug to 1.2m bgl. 3. Groundwater encountered at 12.5m bgl rising to 9.7m bgl after 20 minutes. 4. Installation to 14.0m bgl- 13.0m plain pipe and 1.0m slotted pipe.